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United States
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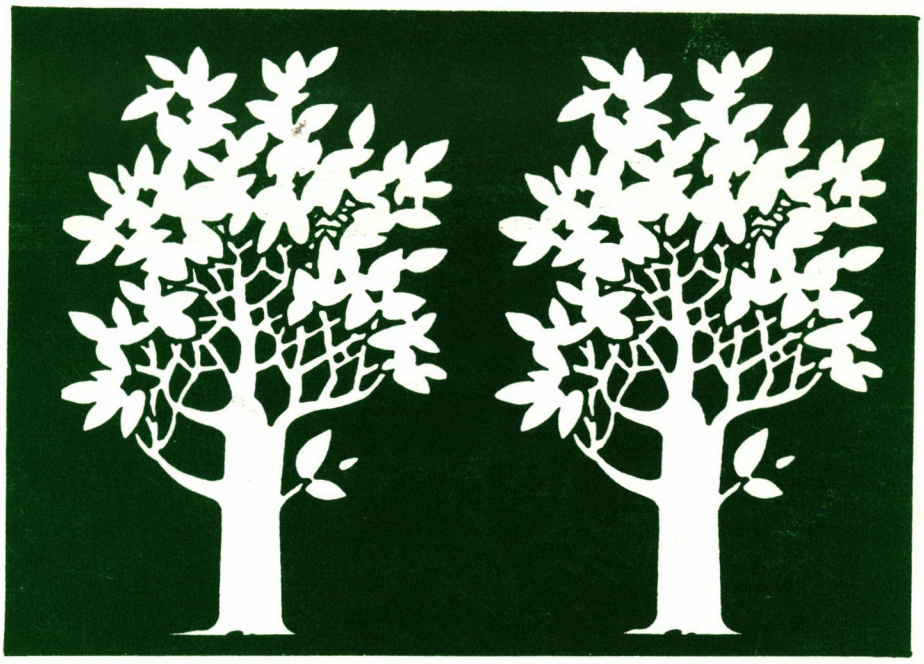
Forest Service

**Forest Pest
Management**

Davis, CA

Almond Tree Foliage Characterization



PROGRAM WIND
COOPERATIVE ATMOSPHERIC RESEARCH

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FPM 87-1
February 1987

ALMOND TREE FOLIAGE CHARACTERIZATION

A Program WIND Report

Prepared by·

Wesley E. Newton
Statistician
U.S. Army
Dugway Proving Ground, Utah

Ronald Barnes
Plant Physiologist
Monarch Laboratory
Chico, CA

John W. Barry
Pesticide Specialist
USDA Forest Service
Davis, CA

U.S. Department of Agriculture
Forest Service
Forest Pest Management
2121C. Second Street
Davis, CA 95616
(916)758-4600

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PREFACE

Program WIND (Winds in Non-Uniform Domains) is a cooperative study sponsored by the USDA Forest Service, Forest Pest Management, State and Private Forestry; the U.S. Army Atmospheric Sciences Laboratory, White Sands Missile Range, NM; and the U.S. Army Dugway Proving Ground, UT. The objective of the study is to obtain information on meteorology, and dispersion and deposition processes for the evaluation and improvement of models that describe wind, turbulence, temperature and humidity, and concentration and deposition of airborne materials over and within forests and complex terrain.

The tasks of this Program are to evaluate and improve:

A. Selected mesoscale meteorological models of turbulence, windspeed and direction, temperature, and humidity over complex terrain.

B. Selected microscale models of turbulence, windspeed and direction, temperature, humidity above and within forest canopies.

C. Models that predict drift, dispersion, concentration and deposition of small particulates, droplets, and tracers and the penetration of these materials into forest canopies.

D. Model performance by identifying and investigating critical elements and processes of the selected models.

The field studies are being conducted in mountain-valley terrain north of Chico, CA to Redding, CA - and east to Lassen National Park. Field measurements began in the summer of 1985 and will end in the fall of 1987.

This sub-study of Program WIND reported herein was initiated and funded by the USDA Forest Service (FS) at the request of Program scientists. Field measurements were conducted under the direction of Ron Barnes, Monarch Laboratory, Chico, CA. Statistical analyses were performed by Wesley E. Newton, U.S. Army Dugway Proving Ground, Utah. From a statistical viewpoint the measurements were limited due to practical considerations. Counting and sizing all leaves on three varieties of almond trees is extremely labor intensive. It was recognized that examination of a greater number of trees would have contributed to the greater statistical confidence of the results. Such could not be justified for the purpose of this sub-study. Nevertheless, we feel the data presented contributes important information on characterizing almond trees. Data from this almond tree sub-study can be applied: to estimate required pesticide spray volume for spray coverage of foliage, to determine tree transpiration, to calculate tree nutrient needs, and to provide canopy structure input for meteorological models that predict air turbulence and airflow within canopies.

Program WIND and the authors acknowledge the cooperation of Bob Hennigan, whose orchard was used for this sub-study, and Ron Cionco, Meteorologist, U.S. Army Atmospheric Sciences Laboratory, who provided field assistance.

ABSTRACT

Three varieties of almond trees were examined to characterize tree foliage by leaf number, leaf size, leaf surface area, and leaf distribution. The information will be used by Program WIND scientists as input to models which predict the amount of pesticide necessary to effect foliage coverage and to calculate air turbulence in the tree canopy for wind models. Significant differences in the characteristics were observed amongst the different varieties; however, statistical differences could not be observed in all comparisons.

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1.0 INTRODUCTION

The U.S. Department of Agriculture, Forest Service (FS); the U.S. Army, Atmospheric Sciences Laboratory (ASL); and the U.S. Army, Dugway Proving Ground (DPG) are principal cooperators in a study called Program WIND (Winds in Non-Uniform Domains). The purpose of the Program is to evaluate meteorological and dispersion models. These models predict wind flow patterns and the dispersion of atmospheric pollution (smoke, dust, and pesticides). The Program is being conducted in a mountain-valley complex north of Chico, CA. The first of four field studies began in June 1985 and the last field study is scheduled for September-October 1987.

An almond orchard, uniform in size, with trees evenly spaced was intensely measured with meteorological instruments. Measurements were made by ASL to study the air turbulence and micrometeorology within, outside, and above the orchard. These intense measurements provided an opportunity to evaluate weather dependent behavior of aerially released sprays. Finite weather measurements also are important inputs to the two FS aerial spray models which were being evaluated under Program WIND.

Concurrent with micrometeorology, another sub-study involved aerial application of a dyed spray to the almond orchard. One objective of this sub-study was to investigate spray deposition on almond leaves. Variables in this sub-study included spray volume, drop size, weather, and aircraft type.

In support of these sub-studies, foliage of three almond tree varieties was characterized by number of leaves per tree, leaf area, leaf weight, and leaf distribution within the tree. This work involved two separate sub-studies. Study 1 involved looking at the whole tree and Study 2 involved looking at the tree in each of six horizontal segments. The work was accomplished by Ron Barnes, Monarch Laboratory, with the help of two student assistants. Field measurements were made in Block 1 of the Hennigan Almond Orchard, Chico, CA during the summber of 1985 (Figure 1.1). The orchard is owned and operated by the Hennigan family.

Data from this almond tree sub-study can be applied: to estimate required pesticide spray volume for spray coverage of foliage, to determine tree transpiration; to calculate tree nutrient needs, and to provide canopy structure input for meteorological models that predict air turbulence and airflow within canopies.

Figure 1.2 - Almond leaf counting in Hennigan Almond Orchard, Chico, CA.

Figure 1.3 - Close-up view of almond tree branch and 1985 crop, Hennigan Almond Orchard, Chico, CA.

Study 2

Percent of the total leaves by distribution within six horizontal levels (Figure 1.4) was determined for each of the three almond tree varieties. The sample trees (one per variety) were located near tower OT-2 on the north end of Block 1, Hennigan Almond Orchard. The tree was divided into six levels as follows:

1	<1.2 meters
2	1.2 - 2.4
3	2.4 - 3.7
4	3.7 - 4.9
5	4.9 - 6.1
6	>6.1

The total number of leaves were counted within each of the six levels.

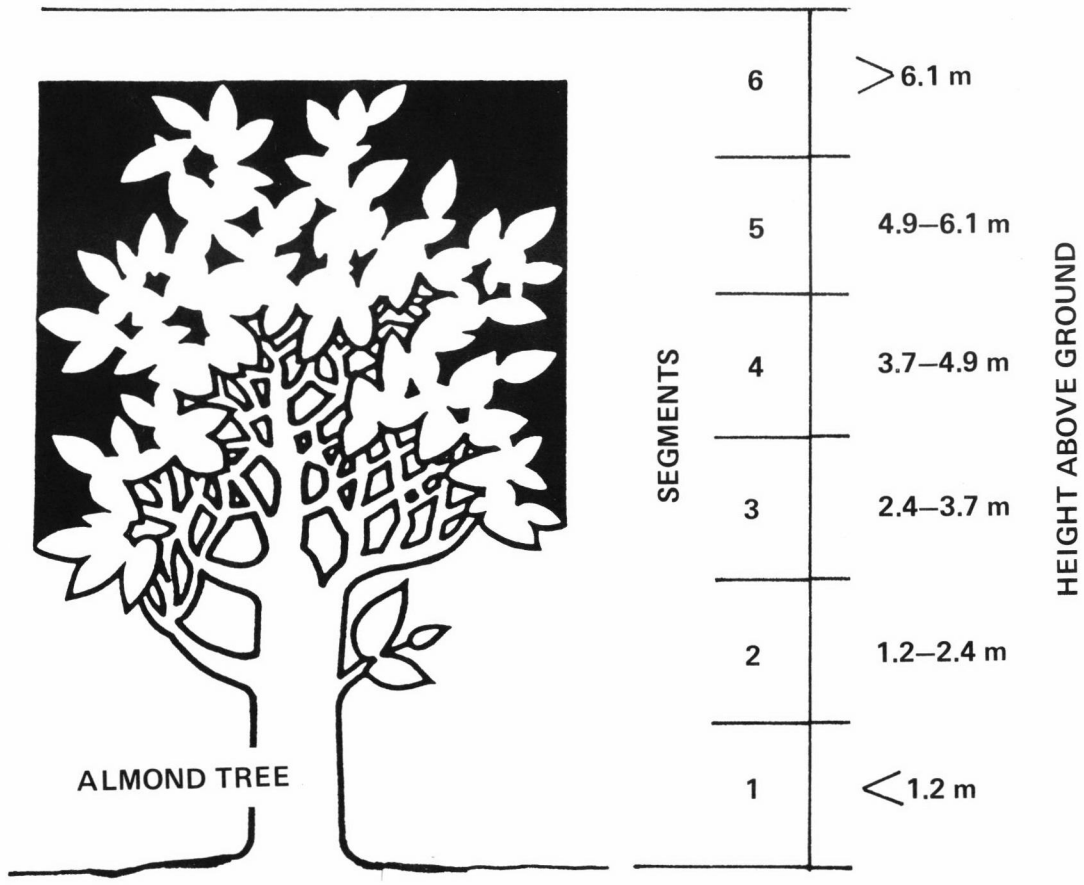

Figure 1.4 - Segmentation of tree for foliage assessment of the six horizontal levels.

Table 3.1 - Percentage number of leaves by

	Harvey			N
	Leaf Area (cm^2)			Lea
	0-5.1	5.2-6.4	6.5+	0-5.1
Trial-1	46	22	32	24
Trial-2	26	23	51	21
Trial-3	33	27	40	43
Average	35	24	41	29

Table 3.2 - Percentage leaf area by almond

Trial-1	33	22	45	15
Trial-2	13	21	66	14
Trial-3	25	26	50	32
Average	24	23	54	20

3.0 RESULTS

Results of the field assessment counts for Study 1 are presented in Tables 3.1 through 3.6 and results for Study 2 are presented in Tables 3.7 through 3.11. A statistical analyses of the results is presented in Section 4.0.

almond variety and leaf area.

	Price							
	on-pariel							
f Area (cm^2)				Leaf Area (cm^2)				
5.2-6.4	6.5+			0-5.1	5.2-6.4	6.5+		
32	44			30	39	31		
29	50			36	32	32		
14	43			50	28	22		
25	46			39	33	28		

variety and leaf area.

27	57			20	38	42		
24	62			29	31	41		
14	54			40	29	31		
22	58			30	33	38		

Table 3.3 - Average almond leaf area - both sides (cm^2).

	Harvey	Non-pariel	Price
Trial-1	11.2	13.3	11.4
Trial-2	12.7	13.6	11.7
Trial-3	12.0	11.7	10.6
Average	12.0	12.9	11.2

Table 3.4 - Average leaf weight (grams).

	Harvey	Non-pariel	Price
Trial-1	0.047	0.052	0.042
Trial-2	0.055	0.057	0.039
Trial-3	0.042	0.059	0.044
Average	0.048	0.056	0.042

Table 3.5 - Number of leaves per tree.

	Harvey	Non-pariel	Price
Trial-1	168,840	163,980	173,134
Trial-2	143,308	94,037	141,624
Trial-3	165,532	159,708	104,648
Average	159,227	139,242	139,802

Table 3.6 - Total leaf area - both sides (m^2).

	Harvey	Non-pariel	Price
Trial-1	189.5	217.9	196.6
Trial-2	183.0	127.4	166.3
Trial-3	198.6	187.5	135.0
Average	190.4	177.6	166.0

Table 3.7 - Number of leaves per tree segment and total per tree.

Horizontal Level (m) [1.]	Harvey	Non-pariel	Price
0-1.2	2,338	645	3,222
1.2-2.4	13,126	18,054	26,125
2.4-3.7	17,631	46,376	26,513
3.7-4.9	25,107	33,851	21,301
4.9-6.1	13,852	25,950	19,583
6.1+	444	4,538	4,887
Total	72,498	129,414	101,631

1. Horizontal levels above ground in meters.

Table 3.8 - Average leaf area - both sides (cm^2).

Harvey	Non-Pariel	Price
10.2	15.9	10.6

Table 3.9 - Leaf area (m^2) per tree - both leaf surfaces by segment.

Horizontal Level (m)	Harvey	Non-pariel	Price
0-1.2	2.4	0.7	3.3
1.2-2.4	13.4	18.4	26.6
2.4-3.7	18.0	47.3	27.0
3.7-4.9	25.6	34.5	21.7
4.9-6.1	14.1	26.5	20.0
6.1+	0.5	4.6	5.0
Total	74.0	132.0	103.6

Table 3.10 - Leaf area (%) by variety and horizontal level above ground.

Horizontal Level (m)	Harvey	Non-pariel	Price
0-1.2	3.2	0.5	3.2
1.2-2.4	18.1	13.9	25.7
2.4-3.7	24.3	35.8	26.1
3.7-4.9	34.6	26.1	20.9
4.9-6.1	19.1	20.1	19.3
6.1+	0.7	3.5	4.8

Table 3.11 - Average leaf weight (grams).

Harvey	Non-pariel	Price
0.041	0.054	0.046

4.0 STATISTICAL ANALYSES

4.1.0 Comparison of the Percentage of the Number of Leaves.

4.1.1 Objective

The objective was to compare the percentage of leaves for three almond varieties for each of three size categories in cm^2.

4.1.2 Experimental Design

A completely randomized two-way factorial analysis of variance (ANOVA) with two main effects was utilized. Three different almond varieties (Harvey, Non-pariel, and Price) were involved. The total number of leaves were counted on one tree of each variety. Two adjacent trees had 50 percent of the leaves counted. Counts were averaged to represent totals per tree. The leaves were further classified into one of three leaf size categories (0-5.1, 5.2-6.4, 6.5+ cm^2). The percentage of leaves for each leaf size category by variety were then computed.

4.1.3 Results and Discussion

No significant differences existed in the average percentage of leaves between the three almond varieties for the two smaller leaf sizes of 0-5.1 cm^2 and 5.2-6.4 cm^2 (Table 4.1.1 and Figure 4.1.1). There was no significant difference between Harvey and Non-pariel for leaf size 6.5+ cm^2, but both were significantly greater than Price (Table 4.1.1 and Figure 4.1.1). It is interesting to note that there is no significant differences in the percentage of leaves between the three leaf sizes for Price (Table 4.1.2 and Figure 4.1.2). Non-pariel shows no significant difference between the two smaller leaf sizes, but both being significantly less than the larger leaf sizes (Table 4.1.2 and Figure 4.1.2). Harvey shows a significant difference between the middle and larger leaf size, but the smaller sized leaves were not significantly different from either the large or middle sized leaves (Table 4.1.2 and Figure 4.1.2).[1].

---

[1]. Note: Fisher's LSD value is used for mean comparisons when the F-statistic for the ANOVA's are significant at the 5% level; Bonferonni's value when not significant (Miliken and Johnson, 1984).

Table 4.1.1 - Comparison of the average percentage of leaves for each variety at each leaf area size (cm^2).[1.]

Variety	0-5.1	5.2-6.4	6.5+
Harvey	35 a	24 a	41 b
Non-pariel	29 a	25 a	46 b
Price	39 a	33 a	28 a

[1.] Averages within a column with the same letter are not significantly different using Fisher's LSD value at 0.05 significance level. S.E.=4.8, n=3.

Table 4.1.2 - Comparison of the average percentage of leaves for each leaf area size (cm^2) within each variety.[1.]

Leaf Area Size (cm^2)	Harvey	Non-pariel	Price
0.-5.1	35 ab	29 a	39 a
5.2-6.4	24 a	25 a	33 a
6.5+	41 b	46 b	28 a

[1.] Averages within a column with the same letter are not significantly different using Fisher's LSD value at the 0.05 significance level. S.E.=4.8, n=3.

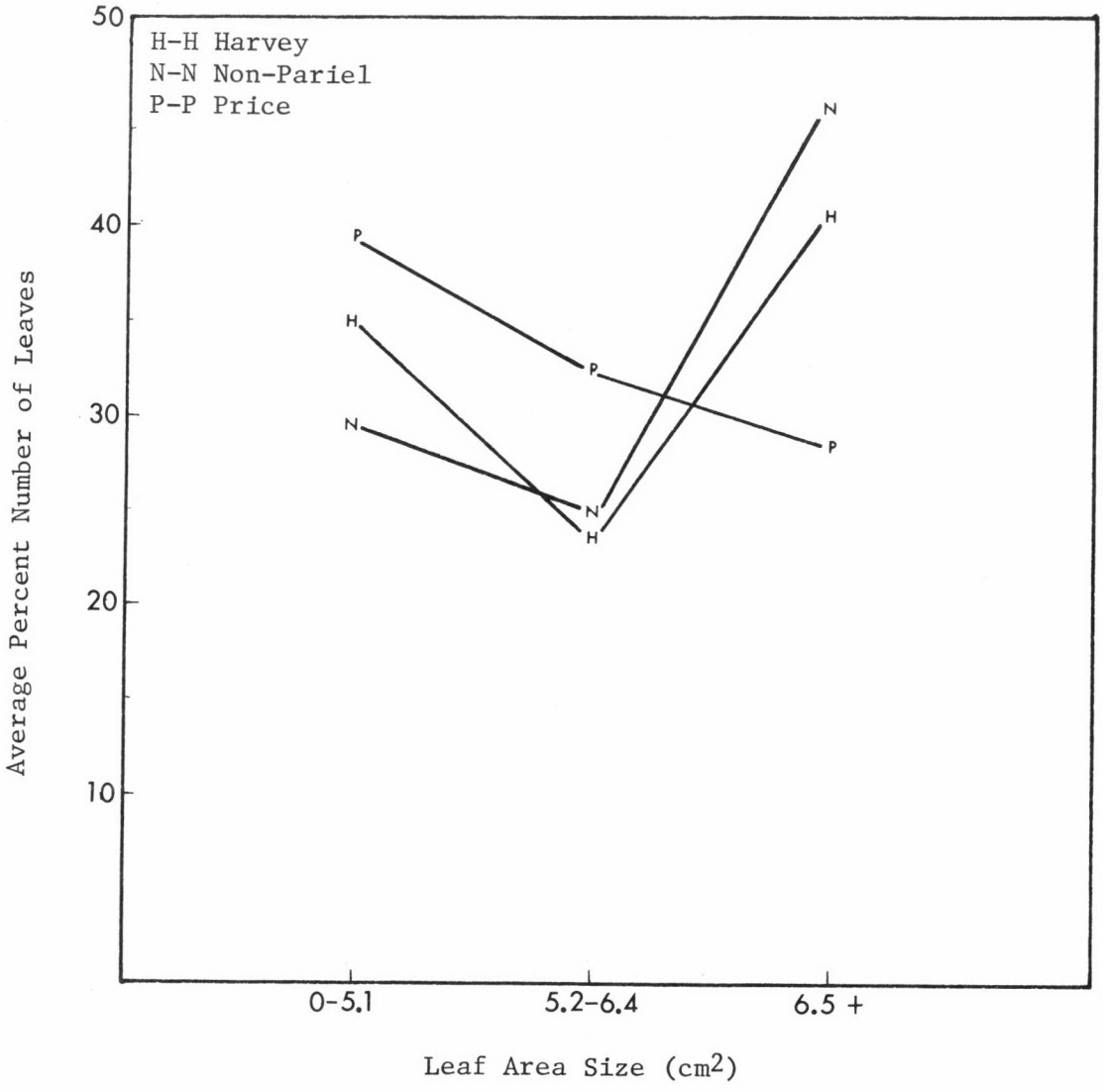

Figure 4.1.1 - Comparison of the average percentage of leaves for each variety at each leaf area size (cm^2).

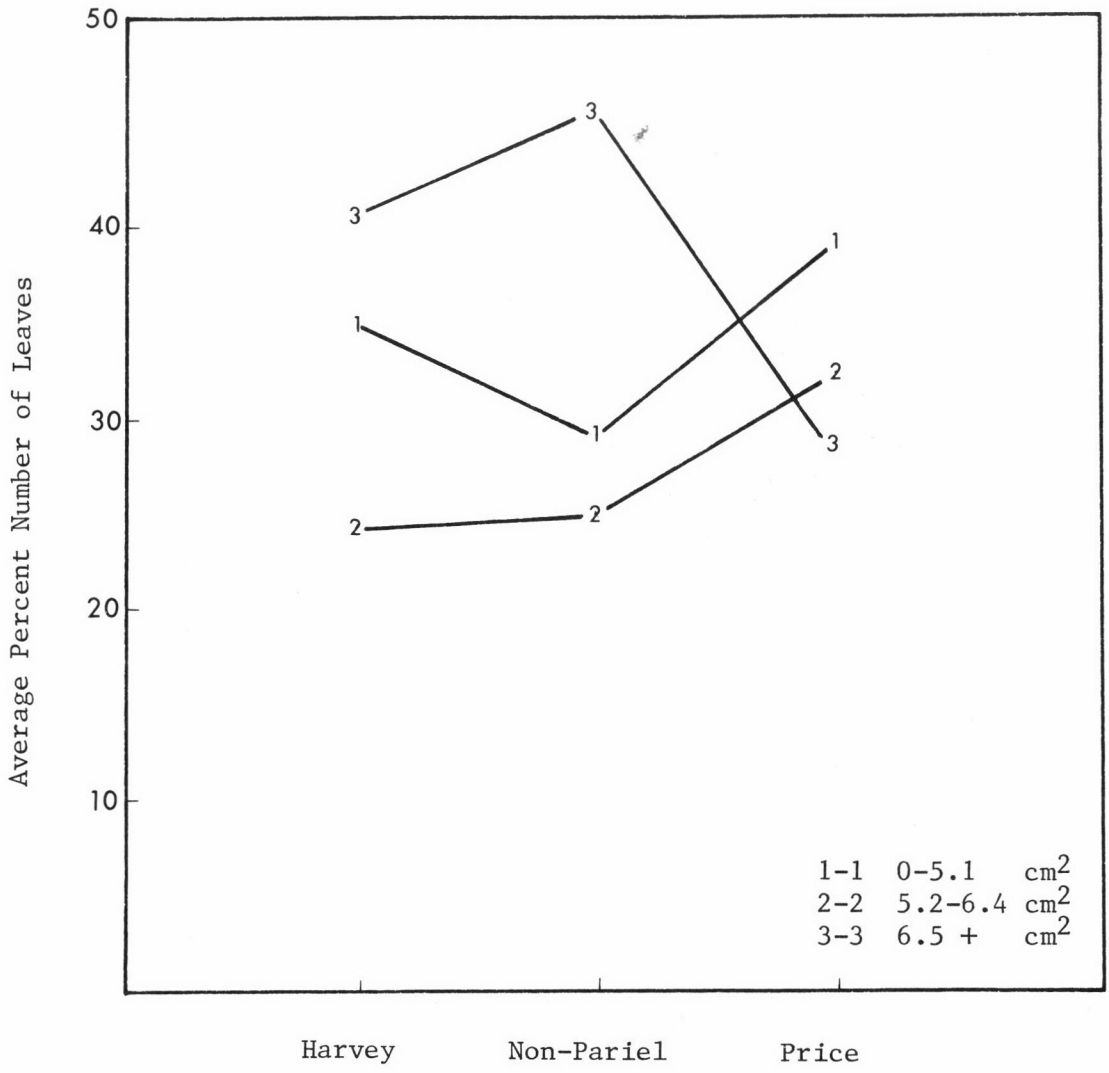

Figure 4.1.2 - Comparison of the average percentage of leaves for each leaf area size (cm^2) within each variety.

4.2.0 Percent Leaf Area Comparisons

4.2.1 Objective

The objective was to compare the percent leaf area attributed to each of the three leaf sizes (leaf size in cm^2) for each of three almond varieties.

4.2.2 Experimental Design

Same as section 4.1.2 except the percent leaf area attributed to each of the three leaf sizes were computed.

4.2.3 Results and Discussion

No significant differences existed in the average percent leaf area between the three almond varieties for the two smaller leaf sizes of 0-5.1 cm^2 and 5.2-6.4 cm^2 (Table 4.2.1 and Figure 4.2.1). There was no significant difference between Harvey and Non-pariel for leaf size 6.5+ cm^2, but both were significantly greater than Price (Table 4.2.1 and Figure 4.2.1). It is interesting to note there were no significant differences in the average percent leaf area between the three leaf sizes for Price (Table 4.2.2 and Figure 4.2.2). Both Harvey and Non-pariel showed no significant difference between the two smaller leaf sizes, but both leaf sizes were significantly less than the larger leaf size of 6.5+ cm^2 (Table 4.2.2 and Figure 4.2.2).

Table 4.2.1 Comparison of the average percent leaf area for each variety at each leaf area size (cm^2).[1]

Variety	0-5.1	5.2-6.4	6.5+
Harvey	24 a	23 a	54 b
Non-pariel	20 a	22 a	58 b
Price	30 a	33 a	38 a

[1] Averages within a column with the same letter are not significantly different using Fishers LSD value at the 0.05 significance level. S.E.=4.5, n=3.

Table 4.2.2 Comparison of the average percent leaf area for each leaf area size (cm^2) within each variety.[1]

Leaf Area Size (cm^2)	Harvey	Non-pariel	Price
0-5.1	24 a	20 a	30 a
5.2 6.4	23 a	22 a	33 a
6.5+	54 b	58 b	38 a

[1] Averages within a column with the same letter are not significantly different using Fisher's LSD value at the 0.05 significance level. S.E.=4.5, n=3.

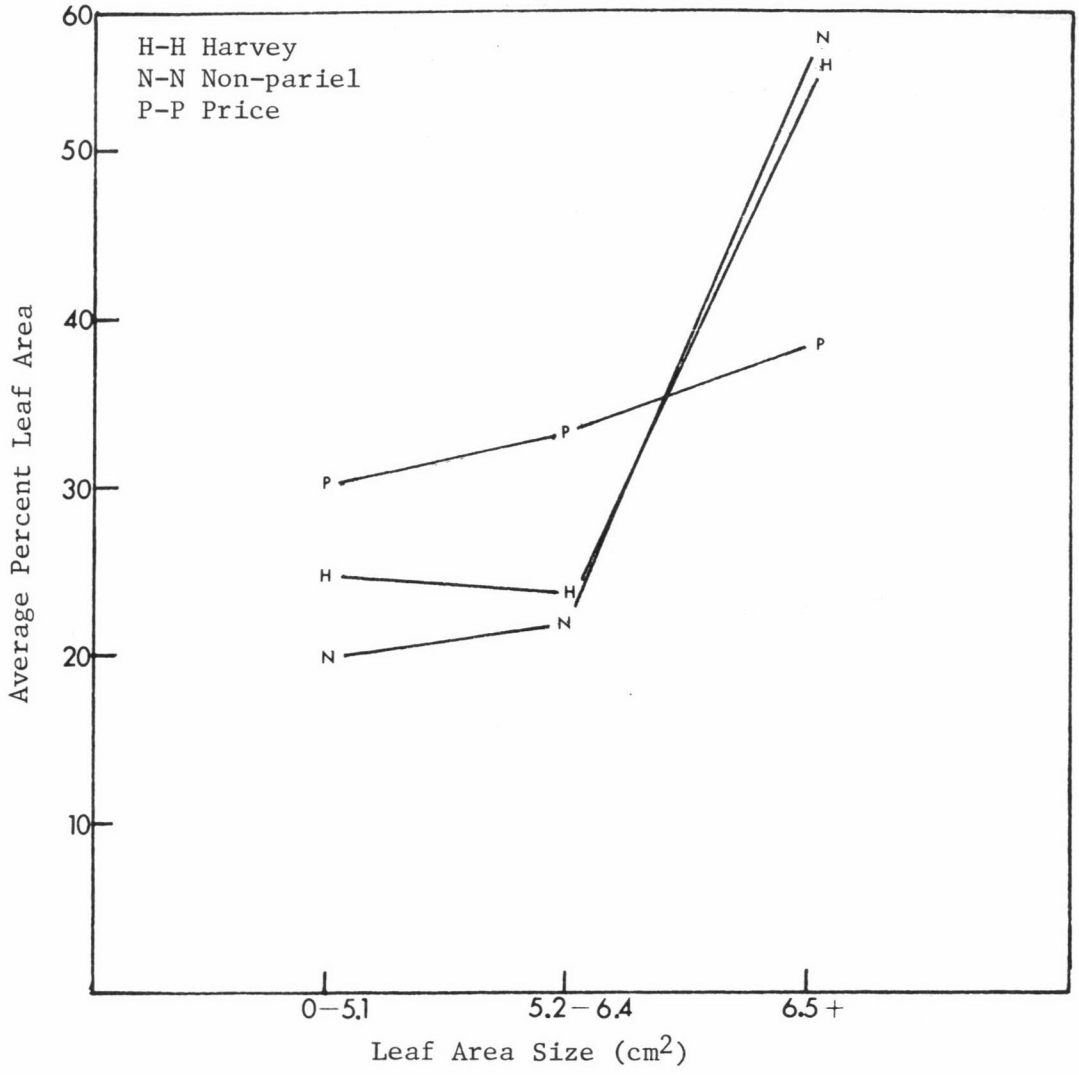

Figure 4.2.1 - Comparison of the average percent leaf area for each variety at each leaf area size (cm^2).

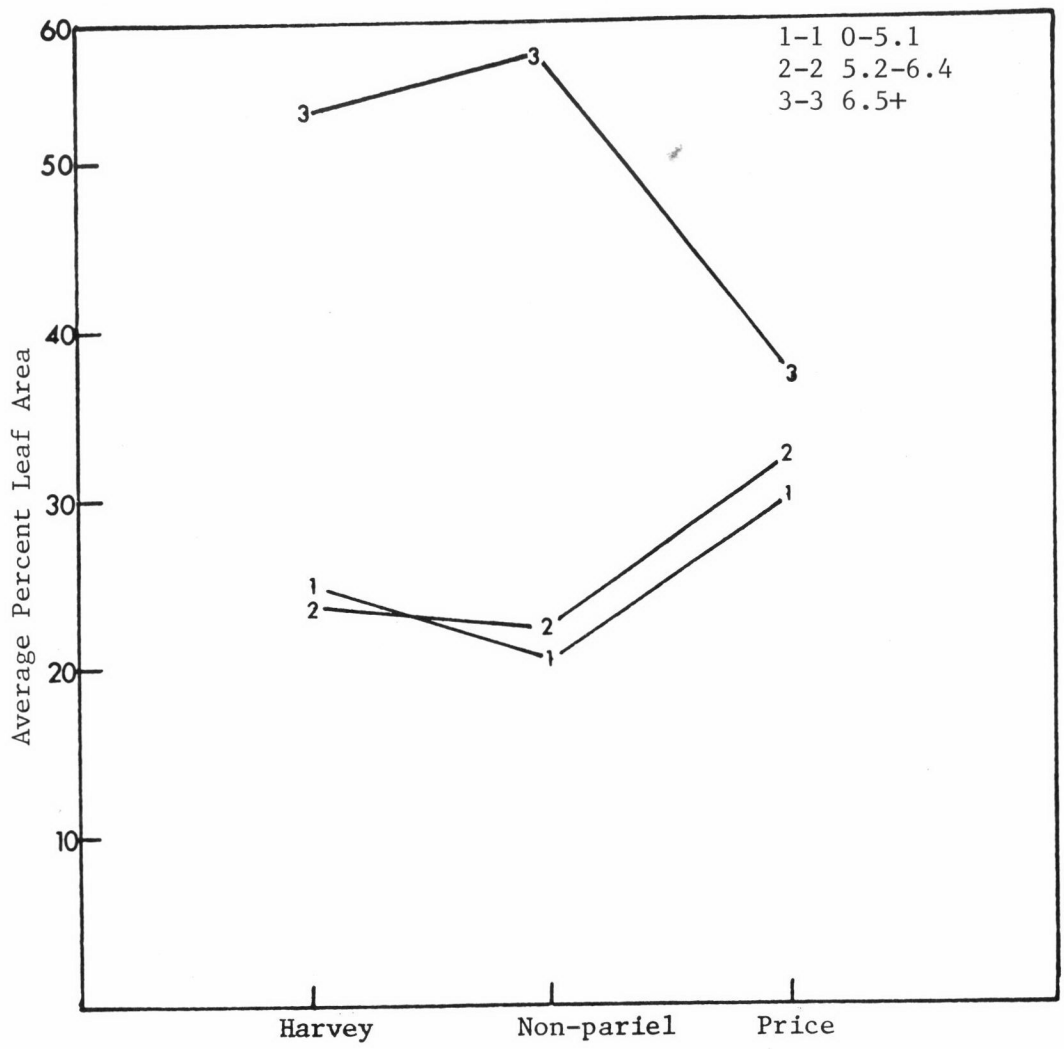

Figure 4.2.2 - Comparison of the average percent leaf area for each leaf area size (cm^2) within each variety.

4.3.0 Average Leaf Area - Both Sides (cm^2).

4.3.1 Objective

The objective was to compare the average leaf area - both sides (cm^2) for three varieties of almond trees.

4.3.2 Experimental Design

A completely randomized one-way ANOVA was utilized. Three different almond varieties, (Harvey, Non-pariel, and Price) were involved. The average leaf area was computed from 200 leaves of each three trees of each variety for comparisons.

4.3.3 Results and Discussion

No significant diffferences exist in the average leaf area - both sides (cm^2) amongst the three almond varieties (Table 4.3.1).

Table 4.3.1 - Comparison of the average leaf area - both sides (cm^2) for three almond varieties.

Variety	Average[1].
Harvey	12.0 a
Non-pariel	12.9 a
Price	11.2 a

[1]. Averages followed by a common letter are not significantly different using Bonferonni's value at the 0.05 significance level. S.E.=0.46, n=3.

4.4.0 Average Leaf Weight (Grams).

4.4.1 Objective

The objective was to compare the average leaf weight (grams) for three varieties of almond trees.

4.4.2 Experimental Design

Same as Section 4.3.2 except average leaf weight was computed using dry weights.

4.4.3 Results and Discussion

Average leaf weights for Harvey and Price were not significantly different from each other, but both were significantly less than Non-pariel (Table 4.4.1).

Table 4.4.1 - Comparison of the average leaf weight (grams) for three almond varieties.

Variety	Average[1].
Harvey	0.048 a
Non-pariel	0.056 b
Price	0.042 a

[1]. Averages followed by a common letter are not significantly different using Fisher's LSD value at the 0.05 significance level. S.E.=0.00258, n=3.

4.5.0 Number of Leaves Per Tree.

4.5.1 Objective

The objective was to compare the average number of leaves per tree for three varieties of almond leaves.

4.5.2 Experimental Design

Same as Section 4.3.2 except total number of leaves per tree was computed for comparison of the three varieties of almond trees.

4.5.3 Results and Discussion

No significant differences exist in the average number of leaves per tree between the three almond varieties (Table 4.5.1).

Table 4.5.1 - Comparison of the average number of leaves per tree for three almond varieties.

Variety	Average[1].
Harvey	159,226 a
Non-pariel	139,242 a
Price	139,802 a

[1]. Averages followed by a common letter are not significantly different using Bonferonni's value at the 0.05 significance level. S.E.=17966, n=3.

4.6.0 Total Leaf Area - Both Sides of Leaf.

4.6.1 Objective

The objective was to compare the average total leaf area (both sides in m^2) for three varieties of almond trees.

4.6.2 Experimental Design

Same as Section 4.3.2, except total leaf area (both sides in m^2) was computed.

4.6.3 Results and Discussion

No significant differences exist in the average total leaf area (both sides in m^2) between the three almond varieties (Table 4.6.1).

Table 4.6.1 - Comparison of the average total leaf area - both sides (m^2) for three almond varieties.

Variety	Average[1].
Harvey	190.4 a
Non-pariel	177.6 a
Price	166.0 a

[1]. Averages followed by common letter are not significantly different using Bonferonni's value at the 0.05 significance level. S.E.=18.7, n=3.

4.7.0 Number of Leaves Per Tree for the Three Almond Varieties by Six Tree Heights (Study 2).

No valid statistical inferences can be made due to a sample size of one tree for each variety. From Figure 4.7.1 it appears there might be a trend for Non-pariel to have more leaves in the middle section of the tree than the other two varieties. It also appears from Figure 4.7.1 that Price has more leaves in the lower section of the tree than Non-pariel. Without further investigation and replications, however, no generalizations can be made about the total population of trees for each variety.

These observations indicate a need for research to determine if there is a statistical difference and if so why. Soil, microclimate, irrigation, and nutrients may be influencing tree vigor on the north edge of the orchard. The influences may differ among varieties.

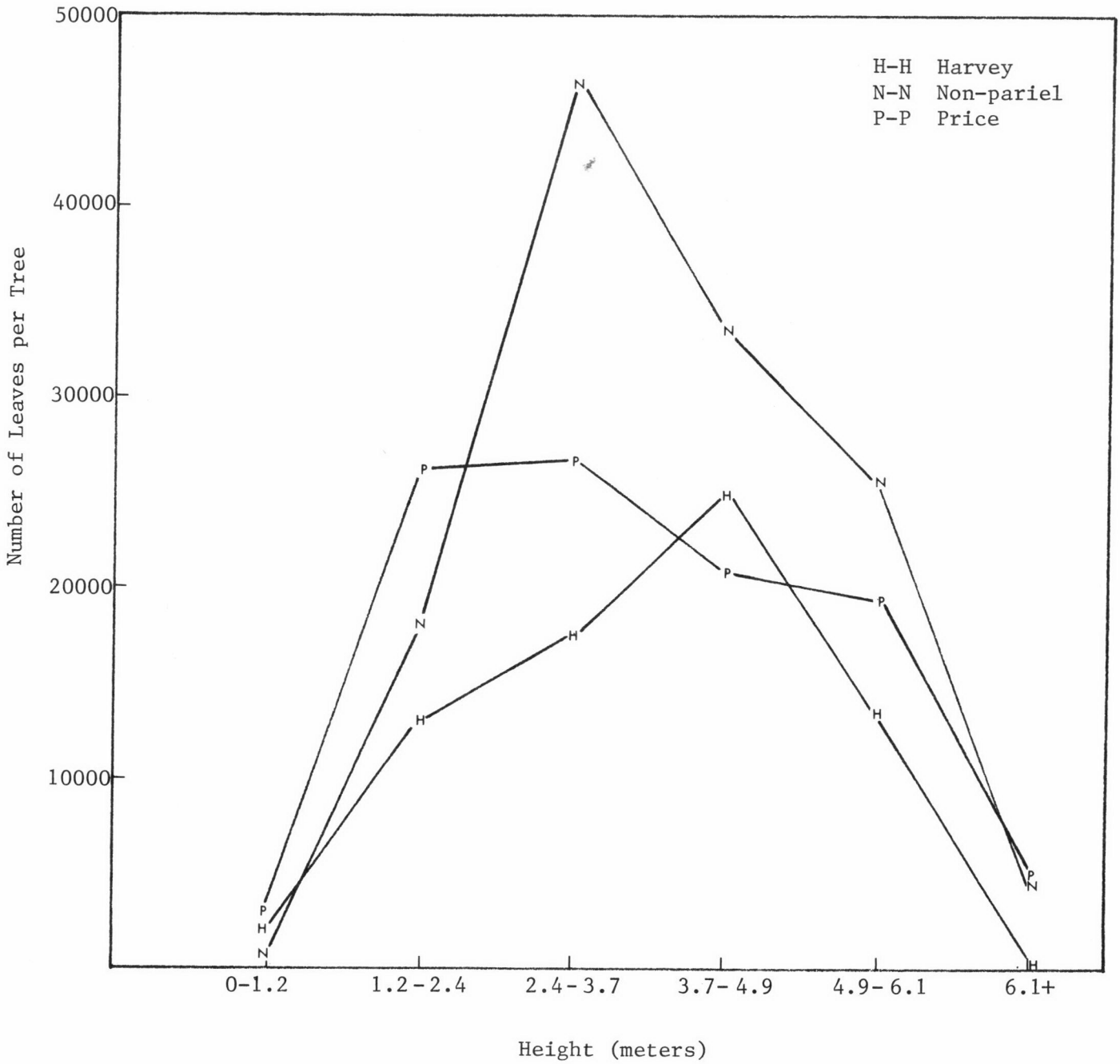

Figure 4.7.1. - Comparison of the number of leaves per tree for each almond variety at each height level within the tree. (Not averages - sample size is one.)

4.8.0 Leaf Area Per Tree - Both Sides (m^2) for the Three Almond Varieties by Six Tree Heights (Study 2).

No valid statistical inferences can be made due to a sample size of one tree for each variety. From Figure 4.8.1 it appears that there might be a trend for Non-pariel to have more surface area in the middle of the tree than the other two varieties with all varieties having about the same at the lower and upper portion of the tree. But it should be reminded that without further investigation and replications, no generalizations can be made about the total population of trees for each variety.

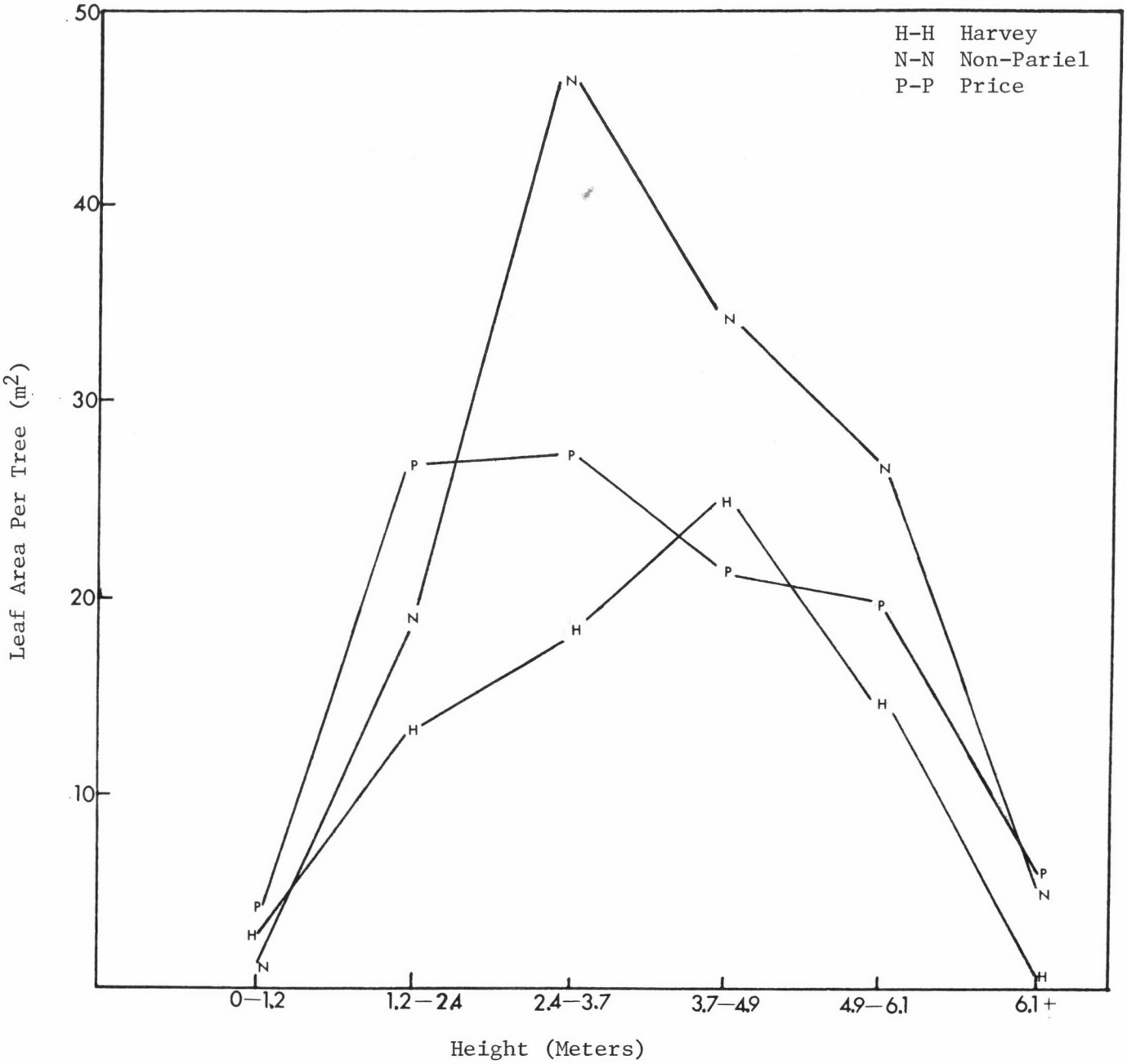

Figure 4.8.1. - Comparison of the leaf area per tree - both sides (m^2) for each almond variety at each height level within the tree. (Not averages - size is one.)

4.9.0 Percent of Leaf Area at Each of Six Tree Heights for Each Variety (Study 2).

No valid statistical inferences can be made due to a sample size of one tree for each variety. From Figure 4.9.1 it appears that there might be a trend for Price to have a smaller percentage of its leaves in the middle part of the tree than the other two varieties. But it should be reminded that without further investigation and replications, no generalizations can be made about the total population of trees for each variety.

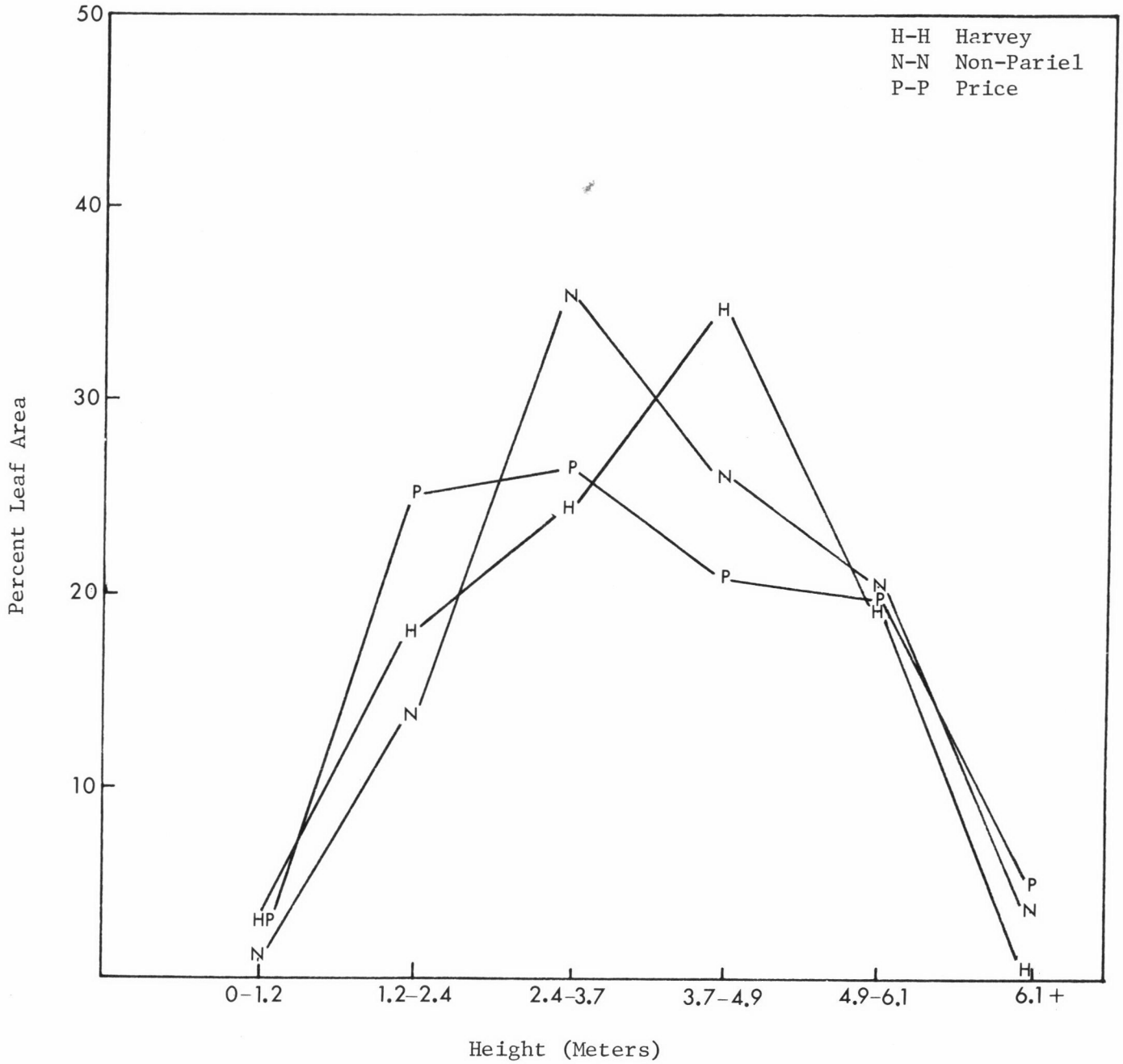

Figure 4.9.1 - Comparison of the percent leaf area at each of six tree heights for each variety.

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